

Lesson 10: Field Monitoring Organization and Protection

Lesson Overview

In this lesson, you will learn about monitoring teams and their instruments as well as how to protect personnel in the field.

Upon completion of this lesson, you will be able to:

- Describe monitoring teams' organization, notification, communications, protection, and training requirements.
- List types of monitoring instruments and air sampling devices and what is measured by each.
- Identify measures to protect field sampling personnel and other critical workers from radiation.

Remember you can access the glossary in one of two ways throughout this course. You can select the glossary button in the top right hand corner of each main content screen. In addition, on content screens you can select underlined words to access their definitions in the online glossary. Selecting an underlined word will take you directly to its definition in the glossary.

This lesson should take approximately **45 minutes** to complete.

Introduction to Field Monitoring

In the event of an incident involving the release of radioactive material into the environment, radiological field monitoring is an important aspect of protecting the public. During a nuclear reactor accident, protective actions should be based initially upon plant conditions and then upon dose projections.

There are, however, many assumptions made in dose projections, and the estimated range of uncertainty between projected and actual off-site doses for severe accidents is at best within a factor of 10, and at worst, off by a factor of 100,000 [source: Nuclear Regulatory Commission Regulation NUREG-1210]. This makes field monitoring an essential requirement for public protection.

Requirements for Organization

Criteria for Preparation and Evacuation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants (NUREG-0654/FEMA REP-1), rev. 1 (October 1980) requires that each responsible organization "provide methods, equipment, and expertise to make rapid assessments of the actual or potential magnitude and locations of any radiological hazards through liquid or gaseous release pathways." This includes:

- Field Team Composition
- Means of Notification
- Estimated Deployment Times
- Communication
- Monitoring Capabilities

- Training Requirements

In this section of the lesson, you will learn what NUREG-0654 specifies for each of these key concepts.

Field Team Composition

According to NUREG-0654, each organization "shall be capable of continuous (24-hour) operations for a protracted period." Plans should specify:

- The number of teams required/available: A typical plan may use five to ten teams (a combination of licensee, state, and local).
- Makeup of those teams (minimum of two members per team): At least one person on the team should know the geography of the area. The availability of additional personnel to staff a second shift must be ensured for extended operations.
- Radiological training: All personnel assigned to monitoring teams will need training in monitoring plans, monitoring procedures, and sampling techniques.

State and local department of agriculture personnel are ideal candidates for the team because they are already trained in appropriate sampling techniques. Sampling procedures should be in place to reflect the laboratory needs for analyses.

State and local sampling teams may be augmented by Federal resources.

Requirements for Organization

Now that we have covered field team composition, you will learn about the means of notification requirements in NUREG-0654.

Means of Notification (1 of 2)

NUREG-0654 specifies:

- "Each organization shall provide for 24-hour per day emergency response, including 24-hour per day manning of communication links."
- "Each organization shall establish procedures for alerting, notifying, and mobilizing emergency response personnel."
- "Each organization shall establish reliable primary and backup means of communications . . . including provision for alerting or activating emergency personnel in each response organization."
- "Provide for updating telephone numbers in procedures at least quarterly."

Means of Notification (2 of 2)

To obtain the personnel necessary to perform field monitoring at any time of the day or night, on weekdays or weekends, the responsible organization must have the capability to alert and fully mobilize personnel.

Primary and backup notification systems should be available, operable and periodically tested. A "telephone tree" is often used to notify field team members when their services are needed. The listing for each member should include office, home and cellular telephone numbers. Pager numbers and the method of accessing the paging service should also be part of the listing as well as any ancillary notification methods. Including addresses in the listing, so that in-person contact can be initiated if communications systems fail, is a good idea, as is updating the list at least quarterly, as NUREG-0654 requires. Numbers, particularly area codes, change from time to time.

Requirements for Organization

Now you will learn about the estimated deployment time requirements in NUREG-0654.

Estimated Deployment Times

Technical staff members need to know the approximate response time of the field team so that they will know how soon they can expect data. Separate response time estimates should be made for responses in good and inclement weather as well as for workday, after-hours, and holiday responses.

There are no required minimum deployment times.

Requirements for Organization

Now you will learn about the communications requirements in NUREG-0654.

Communications

NUREG-0654 states:

- "Each organization shall establish reliable primary and backup means of communications . . . including provision for communicating between...state and local emergency operations centers, and radiological monitoring teams."
- "Conduct periodic testing of the communications system."
- "Communications drills between EOCs and field assessment teams shall be conducted at least annually."

According to the FEMA REP Program Manual, April 2012, field teams and their command post must have access to one communication system that is independent from the commercial telephone system.

Field teams must be able to report the radiological data they have collected to the field team coordinator promptly.

Requirements for Organization

Now you will learn about the requirements to have monitoring capabilities in NUREG-0654.

Monitoring Capabilities (1 of 2)

NUREG-0654 states:

- "Each organization . . . shall provide for offsite radiological monitoring equipment in the vicinity of the nuclear facility."
- "[There shall be] provisions to inspect, inventory, and operationally check equipment at least once each calendar quarter and after each use. There shall be sufficient reserves of equipment to replace those removed for calibration or repair. Calibration shall be at the interval recommended by the manufacturer."

Determining the presence of radioiodines and particulates during the early phase requires that air samples be taken and analyzed. Direct radiation measurements alone cannot differentiate between external exposure from the noble gases (xenon and krypton), iodines, and particulates. Nor would they be practical in determining the internal dose due to inhalation of iodines and particulates. Therefore, both instrumentation measuring gamma exposure rate and air sampling equipment are essential for verifying plume exposure rate.

Monitoring Capabilities (2 of 2)

During the intermediate phase, gamma exposure rate instruments are used to determine the boundaries of the restricted zone, the area within which persons who have not already been evacuated must be relocated. Air sampling equipment is used to determine whether resuspension of deposited radioactive material contributes significantly to dose.

All equipment used for this monitoring must be calibrated, and sufficient reserves of such equipment must be available to replace equipment that breaks or wears out during the heavy use to which it will be subjected. The FRMAC manuals describe the resources available for the Federal response as well as the quality assurance procedures and monitoring techniques used by the Federal response team.

In the next section of this lesson, you will learn more about types of monitoring equipment.

Survey Meters (1 of 5)

Properly calibrated low-range and high-range survey instruments are necessary for direct-exposure measurements during the early phase of the incident.

Low-range Geiger-Mueller (GM) or sealed ion chamber instruments have moveable beta shields that provide open and closed-window measurement capabilities. Readings with the beta window closed yield a gamma-only exposure rate, whereas readings with the window open yield a beta plus gamma exposure rate.

Open-window (beta plus gamma) readings taken at about one meter off the ground and near the ground that significantly exceed closed-window (gamma only) readings indicate that the operator is immersed in the plume. Taking an air sample at that location is warranted.

Open-window (beta plus gamma) readings significantly greater than closed-window (gamma only) readings only near the ground indicate groundshine, and the absence of a significant difference between open and closed-window readings indicates plume shine. In neither of these cases is taking an air sample warranted.

Survey Meters (2 of 5)

During the intermediate phase, gamma exposure rate instruments along with isotopic analysis of the deposited radionuclides are used to determine the boundaries of the restricted zone, the area within which persons who have not already been evacuated must be relocated. Air sampling equipment is used to determine whether resuspension of deposited radioactive material contributes significantly to dose.

All equipment used for this monitoring must be calibrated, and sufficient reserves of such equipment must be available to replace equipment that breaks or wears out during the heavy use to which it will be subjected. The FRMAC manuals describe the resources available for the Federal response as well as the quality assurance procedures and monitoring techniques used by the Federal response team.

Survey Meters (3 of 5)

GM instruments designed for measuring low exposure rates, e.g., tens of mR/hr, may malfunction at high exposure rates, e.g., tens of R/hr, because they become saturated. It is therefore important that a monitoring system include a high-range instrument or instruments capable of measuring higher gamma radiation exposure rates.

Survey Meters (4 of 5)

The time it takes for the positive ion sheath to reach the critical radius is called dead time. After the positive sheath passes the critical radius and moves on toward the cathode, the ionizations become stronger. The time it takes for the positive sheath to move from the critical radius to the cathode is called the recovery time.

Survey Meters (5 of 5)

The ionization pulse (electrical signal) generated must be of sufficient energy to be "seen" by the detector, which does not count anything below this minimum energy. If a GM detector is taken into an intense radiation field, any radiation penetrating the detector during the dead-time period is not counted. Any radiation interacting with the gas during the recovery time period is also not counted and prevents the detector from fully recovering. This effect is called saturation. In such a situation, the instrument will indicate essentially that background levels of radiation are present, when in fact the operator is in a high-radiation area. This is potentially a very serious situation and is the reason why low-range GM instruments must be accompanied by high-range survey meters during accident conditions.

Intermediate-phase operations may require the use of microR meters in addition to the mR and R meters discussed above. The derived response level equal to the 2-rem first-year relocation PAG may be in the tens to hundreds of $\mu\text{R/hr}$. Most microR meters are inorganic scintillation detectors such as 1

" x 1" sodium iodide, thallium-activated detectors [NaI(Tl)]. These instruments are expensive and may be damaged by careless handling. Care should be taken not to damage them while they are in use.

Air Sampler (1 of 2)

An air sampler is a calibrated air pump with the appropriate particulate filter and cartridge type absorber filter for selective collection of radioiodine in the presence of noble gases. Air samplers may be battery-powered or AC-supplied.

When an air sampler is in use, air flows first through the prefilter, trapping particulates such as cesium and up to 10% of the iodines available. The remaining iodines and noble gases (xenon and krypton) pass through the prefilter and enter the cartridge absorber, where the iodines are collected. The noble gases are then exhausted through the other end of the air sampler.

Air Sampler (2 of 2)

One of the most important aspects of early-phase air monitoring is selecting the appropriate sample collection media. Media considerations include:

- **Absorption** - A high efficiency particulate air (HEPA)-type prefilter placed before an absorber type filter medium cartridge can effectively separate the airborne radioactivity into iodine and particulate fractions. Using an appropriate inorganic absorber medium can reduce adsorption of fission product noble gases relative to radioiodine.
- **Charcoal** - Activated charcoal, an organic absorber media, efficiently collects radioiodine, but it also collects a significant portion of the radioactive noble gases. This property makes the charcoal absorber medium unacceptable for use with simple-operating gross radiation measurement instrumentation. (Charcoal may be used in practice exercises as long as silver media is available for actual emergency use.)

If charcoal is to be used, Triethylene diamine (TEDA)-impregnated cartridges are recommended. TEDA acts as a chelating agent to chemically bind the iodines in the cartridge and reduce desorption loss.

- **Inorganic absorber media** - The three commercially available types of inorganic adsorber media are silver zeolite, silver silica gel, and silver alumina. Silver zeolite and silver alumina have higher rejection efficiency for noble gases (that is, they let noble gases go through them) and higher radioiodine retention efficiency (that is, they trap and hold iodine). Silver silica gel is in an activated, dry form, and its retention efficiency is reduced if used in high relative humidity.

Air Sample Media Analyzing System

According to NUREG-0654, each organization "shall have a capability to detect and measure radioiodine concentrations in air in the plume exposure EPZ as low as 10–7 $\mu\text{Ci/cc}$ under field conditions. Interference from the presence of noble gas and background radiation shall not decrease the stated minimum detectable activity."

Prior to removal of the air sample media from the air sampler, samples can be purged with uncontaminated air to remove noble gases left in the interstitial spaces of the cartridge when the air sampler was turned off. This purge is not required but it should not impact the time needed to obtain

sample results significantly. This can easily be accomplished by immediately relocating to a low-background area outside of the plume upon completion of air sampling and energizing the air sampler for an additional five seconds.

A thin-window (1.5–2.0 mg/cm²) pancake GM detector or a 1" x 1" or 2" x 2" NaI(Tl) detector, with either a single-channel or dual-channel analyzer, may be used to measure the radioiodine activity on the absorber cartridge.

Air Sample System Limitations

Portable NaI(Tl) detector systems have some limitations. The more complex (dual-channel analyzer) system does not necessarily provide a more sensitive means of measuring the quantity of I-131 contained in the absorber medium than the simpler (single-channel) model.

Additionally, the smaller NaI(Tl) detectors do not have as good a spectral response as the larger laboratory detectors due to lower resolution and much lower peak-to-Compton continuum ratios.

A small NaI(Tl) system, with the threshold and window discriminators selected for the I-131 photopeak energy (364.48 keV), will include a significant number of counts due to the presence of other high-energy, short-lived isotopes of radioiodine (I-132, 133, 134, and 135).

Because of this effect, users of NaI(Tl) systems should develop detector response curves for absorber medium cartridges counted at varying times after reactor shutdown or use time-corrected dose conversion factors in dose projection calculations.

Example Air Sample

An airborne release may contain a complex mix of radionuclides.

A laboratory receiving samples to analyze must be capable of analyzing samples that contain a complex mix of radionuclides. The sampling time and date must be well documented on the sample.

Most air sampling systems should be able to meet the minimum detectable concentration requirement of 1×10^{-7} $\mu\text{Ci/cc}$ radioiodines. The calculations that should be carried out to ensure a particular system is in compliance with this standard are explained in Lesson 13.

Environmental Sampling Equipment (1 of 2)

Environmental sampling will take place in the intermediate phase of the accident. Many teams will be needed, and each team must be supplied with the appropriate sampling equipment. It is important to prevent cross-contamination of samples, so much of the sampling effort will involve contamination management.

For each type of sample taken (milk, soil, etc.), procedures should be in place establishing how to collect that particular type of sample. Chain-of-custody records must accompany each sample from the time the sample is collected until it reaches the laboratory. The methods used for sampling and for preserving chain of custody should be comparable to those discussed in the FRMAC manuals.

Environmental Sampling Equipment (2 of 2)

The FRMAC manuals describe, in detail, procedures that the Federal teams responding to an incident will employ in collecting environmental samples. These procedures designate the size of the sample to be collected, techniques employed, sample containers to be used, labeling, and chain of custody.

Milk Sample Kits

Milk sample kits from the EPA contain ion exchange method equipment. A new ion exchange cartridge must be used for each milk sample taken, and the funnel must be decontaminated after each use to prevent sample cross-contamination.

Personnel involved in sample taking must be trained in the sample collection procedures to be used and should participate in the six-year-cycle 50-mile Ingestion EPZ exercise. Equipment needed must be available for rapid deployment, exist in quantities appropriate for the accident and be inventoried quarterly.

Milk sampling can be accomplished either by taking a liquid sample or by passing the milk sample through an ion exchange resin. If the laboratory that is going to count the sample would require shipping, the ion exchange method might be the best option.

Requirements for Organization

Now that you have learned about the different types of monitoring equipment, you will learn about the training requirements in NUREG-0654.

Training Requirements (1 of 2)

NUREG-0654 states:

- "Radiological monitoring drills shall be conducted annually, including collection and analysis of all sample media (e.g. water, vegetation, soil, and air), and provisions for communications and record keeping."
- "Health physics drills shall be conducted semi-annually which involve response to, and analysis of, simulated airborne and liquid samples and direct radiation measurements in the environment."
- "[Each organization shall] participate in training."
- "Training and periodic retraining programs shall include radiological monitoring and analysis personnel."
- "Each organization shall provide for initial and annual retraining."

Training Requirements (2 of 2)

Having the equipment available is one thing; having personnel who know how to use it is another. NUREG-0654 requires that field monitoring personnel receive continuing training. Guidance Memorandum "Periodic Requirements-1" (GM PR-1) requires the state to send certification to FEMA annually documenting that personnel have received appropriate training in the operation of any equipment that they must use in the performance of their jobs.

FEMA's Office of General Counsel advises that "compliance with NUREG-0654/FEMA REP-1, Rev. 1 is not necessarily equivalent to compliance with the OSHA standard, nor does compliance with NUREG-0654/FEMA REP-1, Rev. 1 excuse compliance with 29 CFR 1910.120, if applicable."

The Occupational Safety and Health Administration (OSHA) requires that employers train their employees in proper procedures to safeguard their health. Requirements are defined in 29 CFR 1910.120, also known as the HAZWOPER (HAZardous Waste OPERations and Emergency Response) regulations. States are advised to consult their respective attorneys general to determine the applicability of the HAZWOPER regulations in their specific case.

Radiation Protection

You have now learned about field monitoring and its organization, including team composition, notification, deployment, communications, instrumentation, and training requirements.

Another important element of field monitoring is ensuring that workers are protected from radiation in the field. In the next section of this lesson, you will learn about radiation protection for field monitoring.

Dosimetry

NUREG-0654 requires "24-hour-per-day capability to determine the doses received by emergency personnel involved in any nuclear accident, including volunteers. Each organization shall make provisions for distribution of dosimeters, both self-reading and permanent record devices."

Emergency workers use direct-reading dosimeters to keep track of external exposure accrued during the incident and to ensure that they remain within administrative dose limits. Permanent, or more correctly, non-self-reading dosimeters serve as a more precise, legal record of dose; however, they must be processed in a laboratory to determine the dose received.

Electronic Personal Dosimeters

NUREG-0654 includes provisions to ensure that "dosimeters are read at appropriate frequencies and provide for maintaining dose records."

Many jurisdictions are now using electronic personal dosimeters with a range of 0–9,999 mR. Most, if not all, of the personal reading dosimeters (PRDs) have alarms which can be set to exposure limits. This type of dosimeter is easier to use and will eliminate potential problems. Regardless of what dosimeter is used, it must be read at regular intervals to prevent exceeding dose limits. Plans and procedures should specify the required interval at which these readings must be taken.

Non-Direct Reading Dosimetry

The two most common types of non-self-reading dosimeters are:

- **Optically stimulated luminescence technology dosimeter (OSLD)** - An optically stimulated luminescence technology dosimeter (OSLD) uses an Al₂O₃ crystal. The crystal structure changes when exposed to radiation. The amount of radiation exposure is measured by stimulating the Al₂O₃ material with green light. The resulting blue light emitted from the Al₂O₃ is proportional

to the amount of radiation exposure. Many jurisdictions have opted to use OSLDs as their permanent record dosimeter.

- **Thermoluminescent dosimeter (TLD)** - A thermoluminescent dosimeter (TLD) is made of a material, such as lithium fluoride (LiF), that, when exposed to radiation, absorbs the energy from the radiation and transfers it to electrons of the phosphor atoms, which remain in an excited state. When the phosphor is heated, the electrons returning to their lower energy state emit light photons. The amount of light emitted is measured and corresponds directly to the amount of radiation to which the dosimeter has been exposed.

Regardless of which type is used, the dosimeter should be read by a processor accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) or other accreditation program in accordance with ANSI standard N13.11-1983.

Respiratory Protection

Because of its many disadvantages, FEMA does not recommend that respiratory protection be used by state and local personnel responding as emergency workers for off-site missions involving nuclear power plant accidents. Respiratory protection can be effective in preventing inhalation of radioactive material and can take the form of:

- Air purifying respirators: Full-face and half-face masks containing filters
- Air-line respirators: Full-face and half-face masks attached by hose-line to a tank of air at a remote location
- Self-contained Breathing Apparatus: Full-face mask attached to a tank of air carried on person's back

Different types of respiratory protection offer varying levels of protection, measured by inhalation protection factors (PFs). The ambient air concentration of a contaminant in a particular environment divided by the PF of the equipment used will yield the concentration of the contaminant inhaled. For example, if the ambient air concentration of a contaminant is 500 ppm and the respirator used has a PF of 50, the inhaled concentration will be 10 ppm. Air-purifying masks range from in PF from 10 to 50, air-line respirators from 5 to 2,000, and SCBAs as high as 10,000.

Although it provides obvious advantages, respiratory protection also has some drawbacks, including limited air supply (SCBA), visual obstructions (full-face mask), physical stresses of wearing respiratory protection and larger external dose to the wearer due to slower task performance while wearing mask. Each worker who uses respiratory protection must meet the OSHA requirements.

Protective Clothing

Protective clothing, such as one-piece coveralls, limits skin contamination and may reduce beta skin dose. Protective clothing does not protect the wearer from gamma exposure.

Protective clothing may be of the disposable or launderable variety. Whichever type is used, provision must be made for replacement clothing once the teams report to decontamination.

During the intermediate phase, teams may take samples in areas where the public has not been evacuated or relocated. It may be beneficial for any protective clothing worn by these teams to be of a "non-nuclear emergency design" so as not to unduly alarm the public. Conventional work coveralls, rubber boots, and work gloves should serve for contamination management purposes as well as allowing the worker to remain relatively inconspicuous.

Potassium Iodide (KI)

NUREG-0654 requires that each organization make "provision for the use of radioprotective drugs and designate the method by which decision for administering radioprotective drug [will be] made."

Stable iodine, where appropriate, may be used as a prophylaxis to reduce thyroid dose from inhalation of radioiodines. Iodine doses to all workers during emergencies should be managed as described in the EPA's PAG Manual. Because of the slight possibility of an allergic reaction to the iodine, emergency workers should be checked for iodine sensitivity before it is administered. For further information about KI, review Lesson 8.

Decontamination

NUREG-0654 states that each organization shall "establish the means for radiological decontamination of personnel and equipment."

A worker's external exposure does not end until external decontamination is completed. The equipment used by monitoring teams must also be decontaminated, both in the field after each sample is taken, to prevent cross-contamination, and upon conclusion of operations as well.

Lesson Summary

In this lesson, you learned about field monitoring teams, how they are organized, and the measures taken to protect them from radiation. Let's summarize what you have learned in this lesson:

- **Field teams:** To constitute a field monitoring team, a team must have at least two personnel.
- **Means of notification:** Each organization must have in place a 24 hour system to communicate emergency events.
- **Communications:** Field teams must have a backup means of communication that does not rely on the commercial system.
- **Monitoring equipment:** Survey meters, air samplers, and other equipment must be regularly calibrated.
- **Dosimetry:** Dosimeters must be used to record personal doses for emergency workers.
- **Managing Dose:** Respiratory protection, protective clothing, potassium iodide, and other methods may be necessary to protect emergency workers and other critical workers from radiation.

The next lesson will cover field monitoring operations.